実践ノート

Analysis of Freezing of Gait Using the Tri-Axial Accelerometer in Parkinson's Disease

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Abstract

[Purpose] We explored the characteristics of freezing of gait (FOG) in Parkinson's disease (PD) measuring by the tri-axial accelerometer.

[Subjects] A 51-year-old woman who was diagnosed as PD and a healthy control subject aged 41-year-old participated in this study.

[Methods] Tri-axial accelerometer (UNIMEC, Japan) was used to measure vertical, anterior-posterior, and medio-lateral accelerations. The sensor was attached at the upper sacral area. In the healthy subject, task was free walking. The patient with PD walked under two walking conditions: (1) freely, and (2) dual tasking condition (carrying a tray with full glass of water).

[Results] In the patient with PD, "trembling in place" as a subtype of FOG was provoked by dual tasking. During trembling in place, we found that 1) mono-phased pattern or reduction of the first positive peak acceleration in the vertical direction, 2) decreased peak positive acceleration in the anterior-posterior direction, and 3) large percentages of power in the high frequency band. Auto-correlation coefficient of the anterior-posterior acceleration data was marked decreased during dual tasking condition compared to free walking, but was near normal during FOG.

[Conclusion] These findings suggest that, in our patient, (1) "trembling in place" is characterized by a combination of the reduced acceleration to propel the body forward and the increased step frequency, (2) bilateral coordination of gait, in part, may rely on cognitive function, and (3) bilateral uncoordinated gait may be a provoking factor of FOG, not a characteristics during FOG.

Key words: Parkinson's disease, freezing of gait, tri-axial accelerometer

Introduction

Freezing of gait (FOG) is one of the most disabling symptoms in advanced Parkinson's disease (PD)[1]. FOG interferes with daily activities, affects quality of life and is strongly associated with fall[2),3)].

FOG is characterized by feeling of "being glued to the floor". However, FOG can differentiate as three subtypes ("total akinesia", "trembling in place", and "shuffling with small steps")[4)]. Shuffling with small steps and trembling in place are the most common manifestations of FOG, but total akinesia is rare[4)].

FOG is the context dependent episode, thus, occurs in various situations, such as turning, gait initiation, passing through a narrow space, and just before reaching destination. Many patients with PD have experienced the FOG in the domestic environment than in the examination room. Thus, it is necessity to assess the FOG while being at home.

Although several studies using laboratory based objective gait analysis methods have been reported on "trembling in place"[5–9)], these methods are impractical in clinical setting. Therefore, clinical assessment of FOG is largely based on subjective methods[10),11)].

Recently, quantitative gait analysis using the tri-axial accelerometer has been reported[12–14)]. Accelerometer has potential clinical utility to assess in the home environment where FOG occurs most commonly. However, there is no study using accelerometer attached at the upper sacral area to investigate the characteristics of FOG. The purpose of this study was to explore the characteristics of FOG by the tri-axial accelerometer.

Methods

Subjects

A 51-year-old woman who was diagnosed as PD and a healthy control subject aged 41-year-old participated in this study. The patient with PD diagnosed as juvenile PD at 26-year-old, and received the pallidotomy in right side at 42-year-old. She had been prescribed following daily dose medications; Levodopa (3 T), Pramipexole (0.125 mg 6 T), Amantadine (50 mg 6 T), and Pergolide (50 μg 6 T). Her Hoehn-Yahr stage was graded 3 during the on-phase. Unified Parkinson's disease rating scale (UPDRS) motor examination session was 18 points. FOG as sub item of UPDRS ADL session was graded 3. FOG questionnaire (FOGQ) was 16 points.

They provided their written consent after receiving detailed information about the study design and methods.

Procedure

Tri-axial accelerometer (UNIMEC, Japan) was used to measure vertical, anterior-

posterior, and medio-lateral accelerations. The sensor was attached at the upper sacral area. In the healthy subject, task was free walking. The patient with PD walked under two walking conditions: (1) freely, and (2) dual tasking condition (carrying a tray with full glass of water)[15),16)]. The patient was measured during the on-phase of the medication cycle at her home.

Acceleration data were sampled at a rate of 1000 Hz. Sampling data were analyzed using the analysis software (WAS, UNIMEC, Japan). Acceleration signals were low pass filtered using Butterworth filter with a cut off frequency set at 6 Hz prior to further analysis. Fast Fourier transformation (FFT) was used to obtain the power spectrum from the averaged acceleration data.

The autocorrelation functions of the acceleration signals were calculated to investigate the step asymmetry. Auto-correlation analysis was performed using the software, SPSS version 16. The lag was set at the time of 1 step.

Results

In the normal healthy subject, vertical acceleration was observed to follow a highly repeatable bi-phased pattern (Figure 1). During free walking, anterior-posterior accelerations of the patient with PD showed the asymmetry compared with those of the healthy subject (Figure 2). Figure 1 and 2 show the accelerations data during 3 seconds steady gait after 3 teps from gait initiation.

In the patient with PD, “trembling in place” as a subtype of FOG was provoked by dual tasking. We could monitor the acceleration data during and after “trembling in place” as shown in figure 3. Figure 3 shows the accelerations data during 9 seconds. During FOG, the vertical acceleration was characterized by a mono-phased pattern or reduction of the first positive peak phase. In the anterior-posterior direction, the peak positive acceleration was decreased during FOG compared with after FOG. The distances of peak to peak positive acceleration were replaced narrow during FOG (Figure 3).

The high frequency band during FOG was increased more than that after FOG and that during free walking. Auto-correlation coefficient of the anterior-posterior acceleration data was marked decreased during dual tasking condition compared to free walking,

Table 1　Characteristics of anterior-posterior acceleration data

		mean of frequency(Hz)	auoto-correlation coefficient
normal healthy subject		1.95	0.679
PD	free walking	1.71	0.451
	dual tasking	1.46	0.165
	FOG (trembling in place)	2.93	0.595

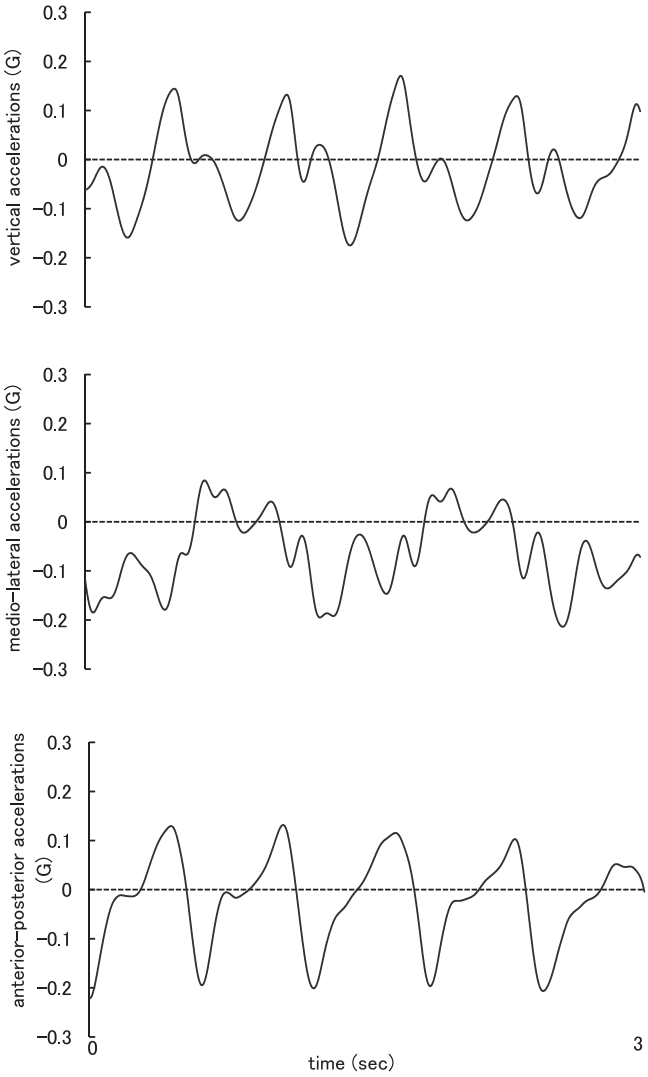

Figure 1　Accelerations data in normal subject
The vertical acceleration was observed to follow a highly repeatable bi-phased pattern.

but was near normal during FOG (Table 1).

Discussion

We found that "trembling in place" in our patient is characterized by a combination of the reduced peak positive vertical and anterior accelerations and the large percentage of power in the high frequency band. The accelerometer placed close to the center of gravity of the body can produce a profile comparable to that associated with ground reaction

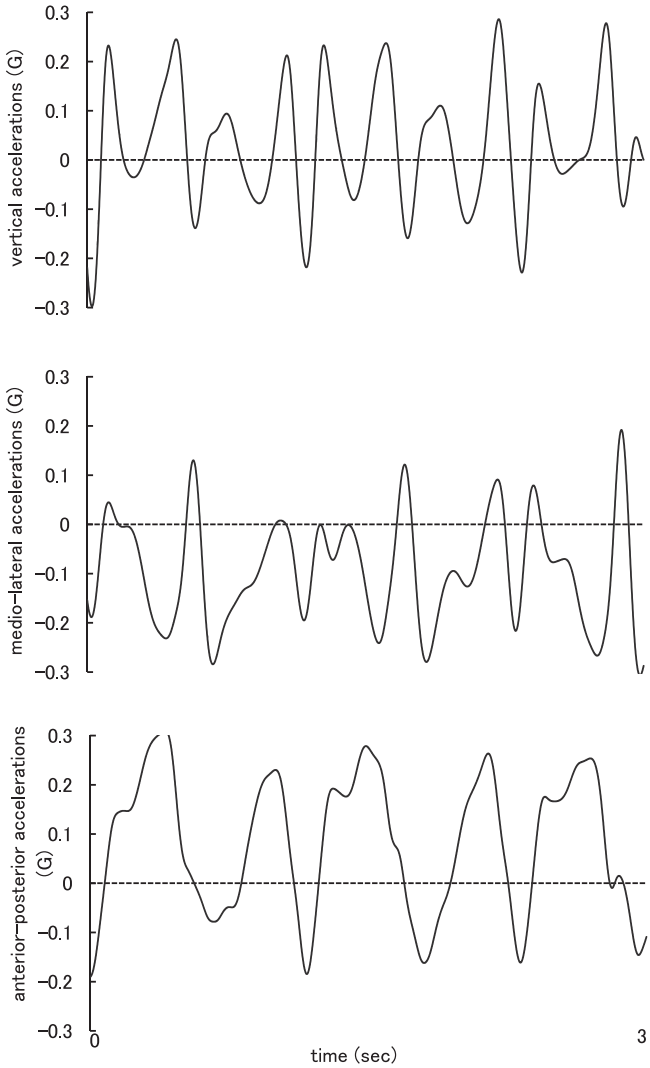

Figure 2　Accelerations data in patient with PD (free walking)
The anterior-posterior accelerations of the patient with PD showed the asymmetry compared with those of the healthy subject.

forces observed during walking[11]. Positive vertical trunk accelerations are evident at the initial contact and the terminal stance phase with negative accelerations during mid-stance[11]. Decreased ankle plantar moments at push-off are reflected in the vertical accelerations[11]. In the anterior-posterior direction, the peak positive accelerations are associated with the push-off phase of terminal stance[12]. Thus, our acceleration data in the patient during FOG may reflect the decreased ankle plantar moments during push-off. Since peak ankle plantar moment is known as the strongest predictor of step length, our acceleration data may indicate severely reduced step length. On the other hand, power

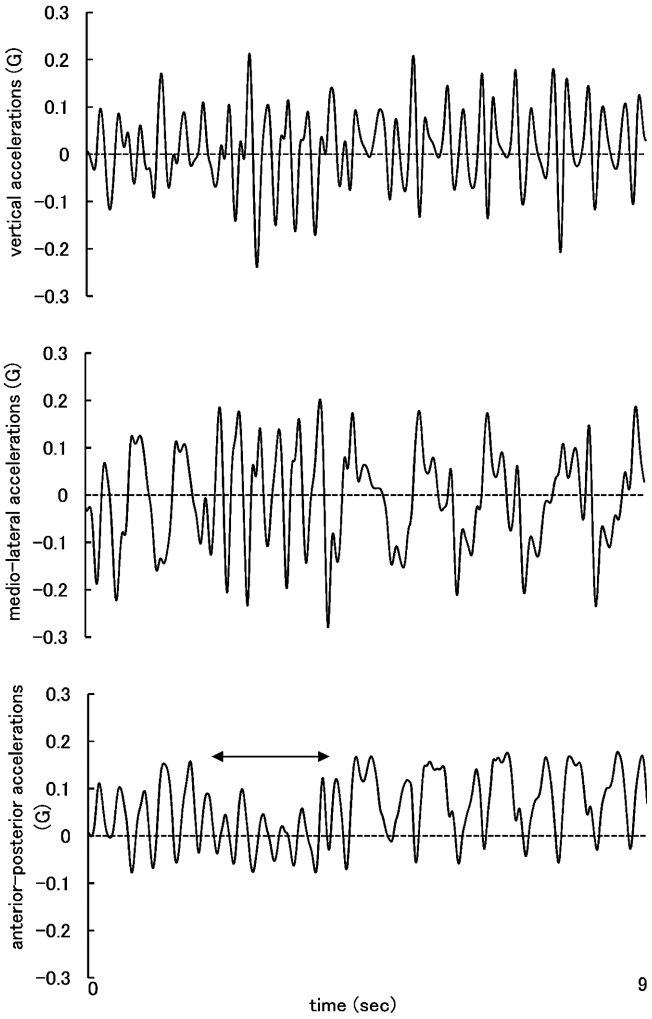

Figure 3　Accelerations data in patient with PD (dual tasking)
Arrow: trembling in place
The vertical acceleration was characterized by a mono-phased pattern or reduction of the first positive peak phase. In the anterior-posterior direction, the peak positive acceleration was decreased during FOG compared with after FOG. The distances of peak to peak positive acceleration were replaced narrow during FOG.

spectrum of the acceleration signals during walking means the step frequency[13]. The large percentage of power in the high frequency band shown during FOG may reflect the increased step frequency.

Therefore, we speculate that the accelerometer can provide the characteristics of "trembling in place" which is a combination of severely reduced step length superimposed on markedly increased cadence of walking[9]. The accelerometer may have a possibility to assess the FOG quantitatively in the domestic environment where FOG occurs most com-

monly.

It has been reported that excessive inhibition of the mesencephalic locomotor regions (MLR) as a result of disturbed basal ganglia output and a decrease in cortical excitation of the brainstem elicit decreased step length in PD[17]. Although little is known about the neuronal mechanism underlying the increased stepping frequency during FOG, it is speculated that the increased cadence results in a compensatory mechanism for decreased step length.

On the other hand, auto-correlation coefficient of acceleration data measured by accelerometer attached at the lower trunk during walking means step symmetry and stride regularity[14]. In our patient, auto-correlation coefficient during dual tasking was markedly decreased compared to that during free walking. Dual tasking is well known as provoking factor of FOG[1),16]. Thus, it can raise the possibility that bilateral uncoordinated gait and marked gait asymmetry are associated with FOG. In fact, it has been reported that an ambulatory gait analysis study using pressure sensitive insole has shown that stride-to-stride variability is markedly increased among PD patients with FOG compared to those without FOG. The result from our study was consistent with that of Plotnik et al[6),18]. Bilateral uncoordinated gait may be a provoking factor of FOG, not a characteristic during FOG. When gait asymmetry alters beyond a certain threshold, it may be lead to the appearance of FOG. Detection of gait asymmetry may be useful to predict the FOG.

Excessive inhibition of the MLR as a result of disturbed basal ganglia output can induce the bilateral uncoordinated gait[17]. Supplementary motor area (SMA) which is projected the neuronal output from the BG also regulates the bilateral coordination of movements[19]. Impaired neuronal output from the BG to the SMA may result in uncoordinated bilateral control of gait. Furthermore, it was suggested that in PD patients, but not in healthy controls, the SMA is activated asymmetrically during the control of volitional walking[19]. However, dual tasking predisposed to gait asymmetry in our patient. This means that (1) gait asymmetry might be associated with distribution of attention, and (2) bilateral coordination was, in part, regulated by cognitive function.

Frontal cortical regions are used to control movements using attentional processes. When the BG is defective due to PD, automatic movement is compromised. As a result, people with PD appear to be reliant on frontal lobe attentional mechanisms to sustain the execution of movement[20]. When 2 activities are performed at the same time, one activity is controlled by defective BG while attention is focused on the other activity. Therefore, patients with PD benefit from focusing their attention on performing one task at a time.

In healthy subjects, their gait is essentially automatic. Gait symmetry is regulated by lower-level processes when gait is automatic. When gait becomes less automatic due to

BG insufficiency, gait symmetry may rely on cognitive function (attention)[21]. For the reason, in our patient, bilateral coordination might become sensitive to dual tasking.

There are several limitations in this study. First, this is single case study. Further research participated more subjects is needed to investigate the validity to assess the FOG by the accelerometer. Second, it is possible that accelerometer sensor attached at the upper sacral area is affected by acceleration of gravity by the slant of the pelvis during walking. Third, accelerometer can not provide the information on an incomplete shift of the center of pressure from one foot to the other, which often takes place during freezing. Although having the limitations of measuring, accelerometer can provide the quantitative data of the FOG in daily life situation. From this standpoint, accelerometer has advantages when compared with other quantitative methods. Therefore, we propose that accelerometer may be the useful and practical tool to assess the FOG.

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